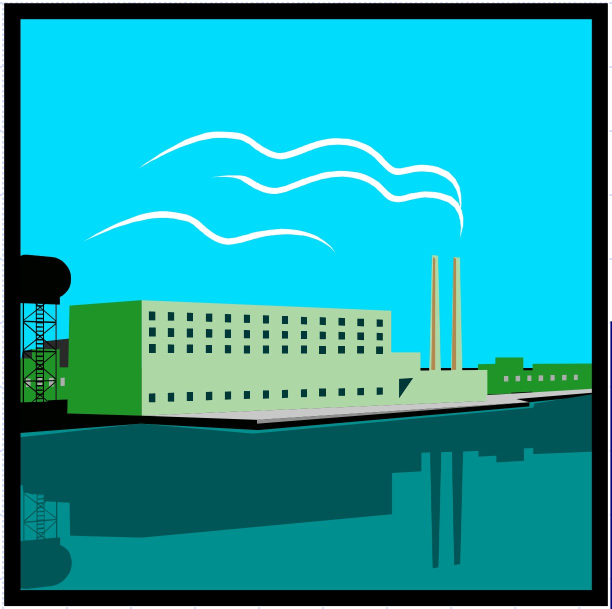
Cleanroom Energy Benchmarking

William Tschudi
Stephen Fok
Kathleen Benshine
Peter Rumsey
July 25, 2001

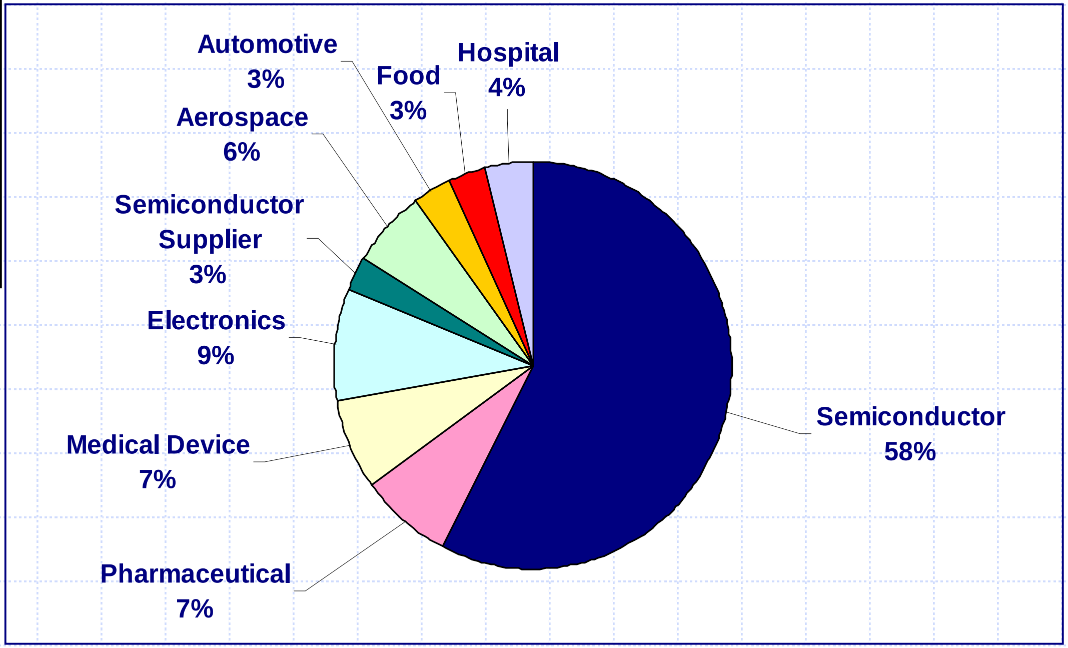
Acknowledgements:

Pacific Gas and Electric Company; Rumsey Engineers

Cleanroom Energy Benchmarking



- Many industries have Cleanrooms
- 4.2 million sq.ft. in CA



Why Benchmark High-tech Buildings?

The California market is large and growing:

- 9400 GWH in 1997 (all high tech buildings)
- 4.2 million sq. ft. of operating cleanrooms
- Semiconductor and Biotech exhibited high growth in last few years

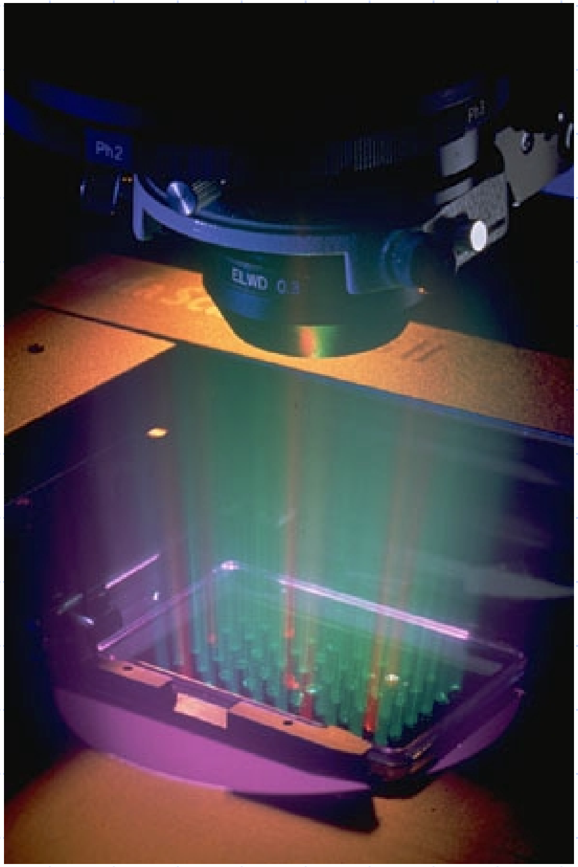
The Benchmarking Process

- Develop a general plan
- Enlist Benchmarking participants
- Develop Site specific plan
- On-site measurement
- Draft site report
- Final customer and anonymous report
- Enter in data base/post web site

Need for common metrics

Cleanroom Metrics

Central Plant Metrics



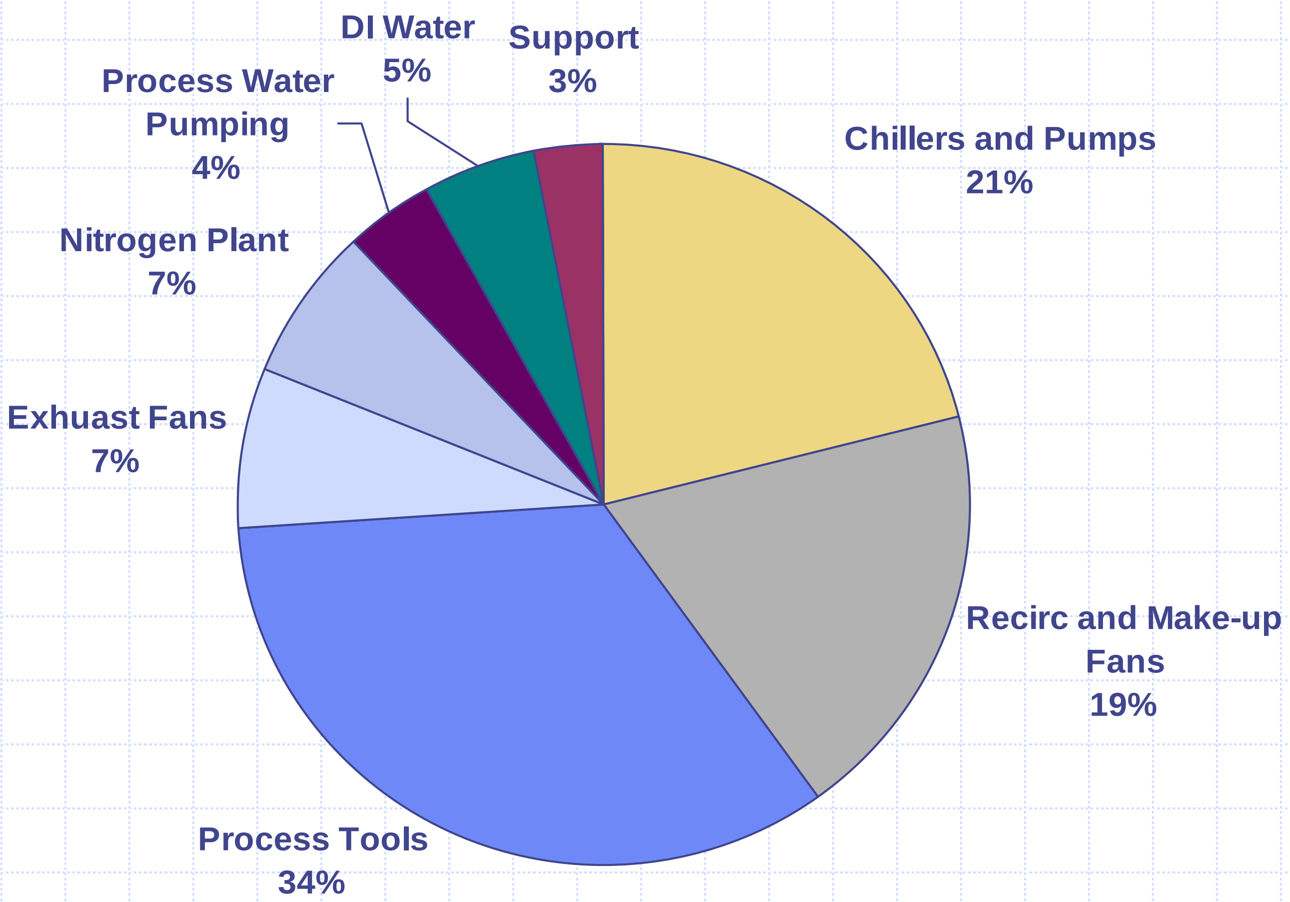
Cleanroom metrics

- Recirculation air handler – cfm/kW
- Recirculation air flow – cfm/sf
- Make-up air handler – cfm/kW
- Make-up air flow – cfm/sf
- Exhaust system efficiency – cfm/kW
- Cleanroom air changes – ACH/hr, ft/sec
- Annual energy cost - $/sf
- Annual energy use – kWh/sf/yr

Central Plant metrics

- Chiller efficiency – kW/ton
- Cooling tower efficiency – kW/ton
- Condenser water pump efficiency – kW/ton
- Chilled water pump efficiency – kW/ton
- Hot water pump efficiency – kW/ton

Energy Use Breakdown Production Cleanroom

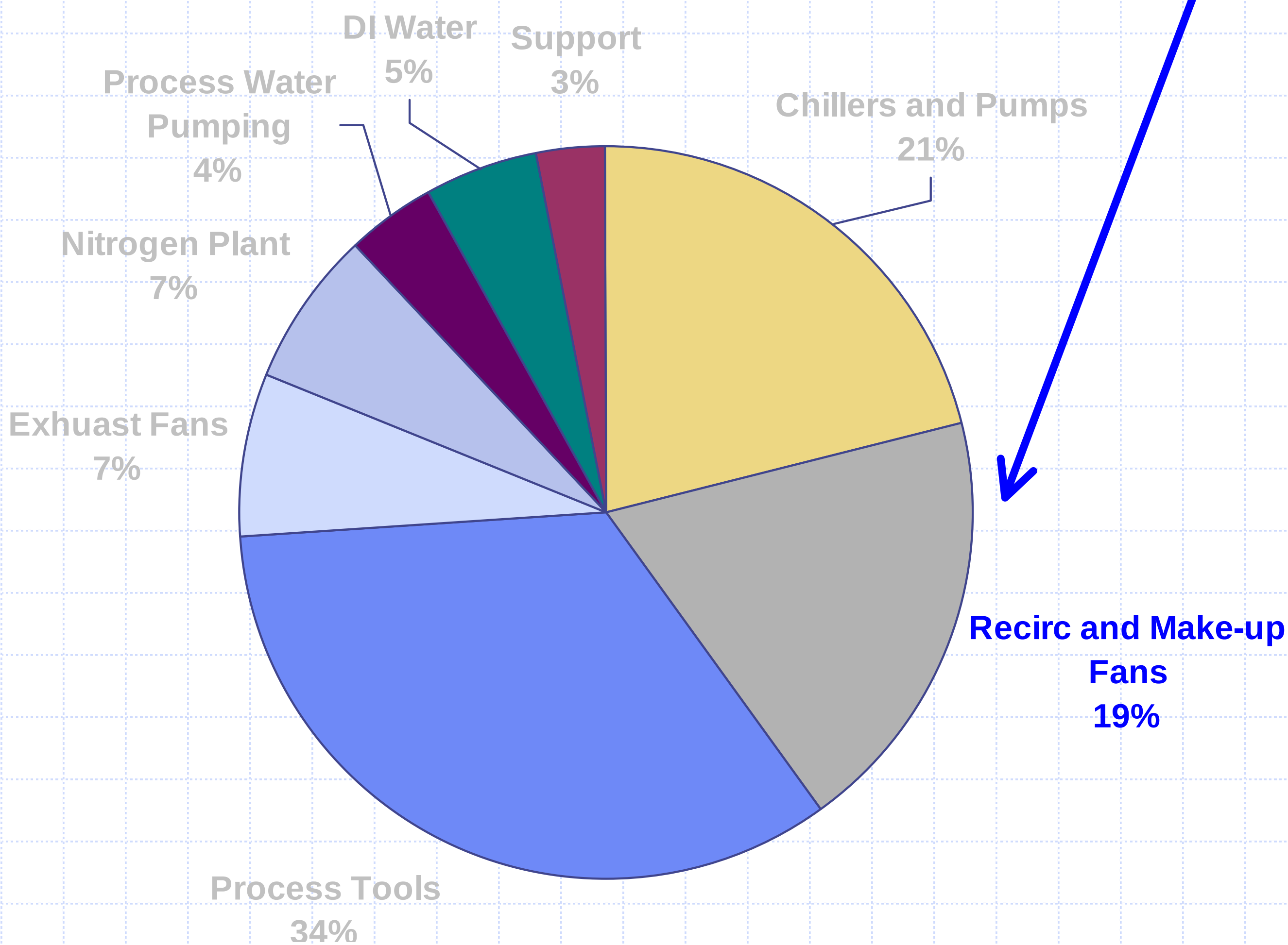


Benchmarking Data Base

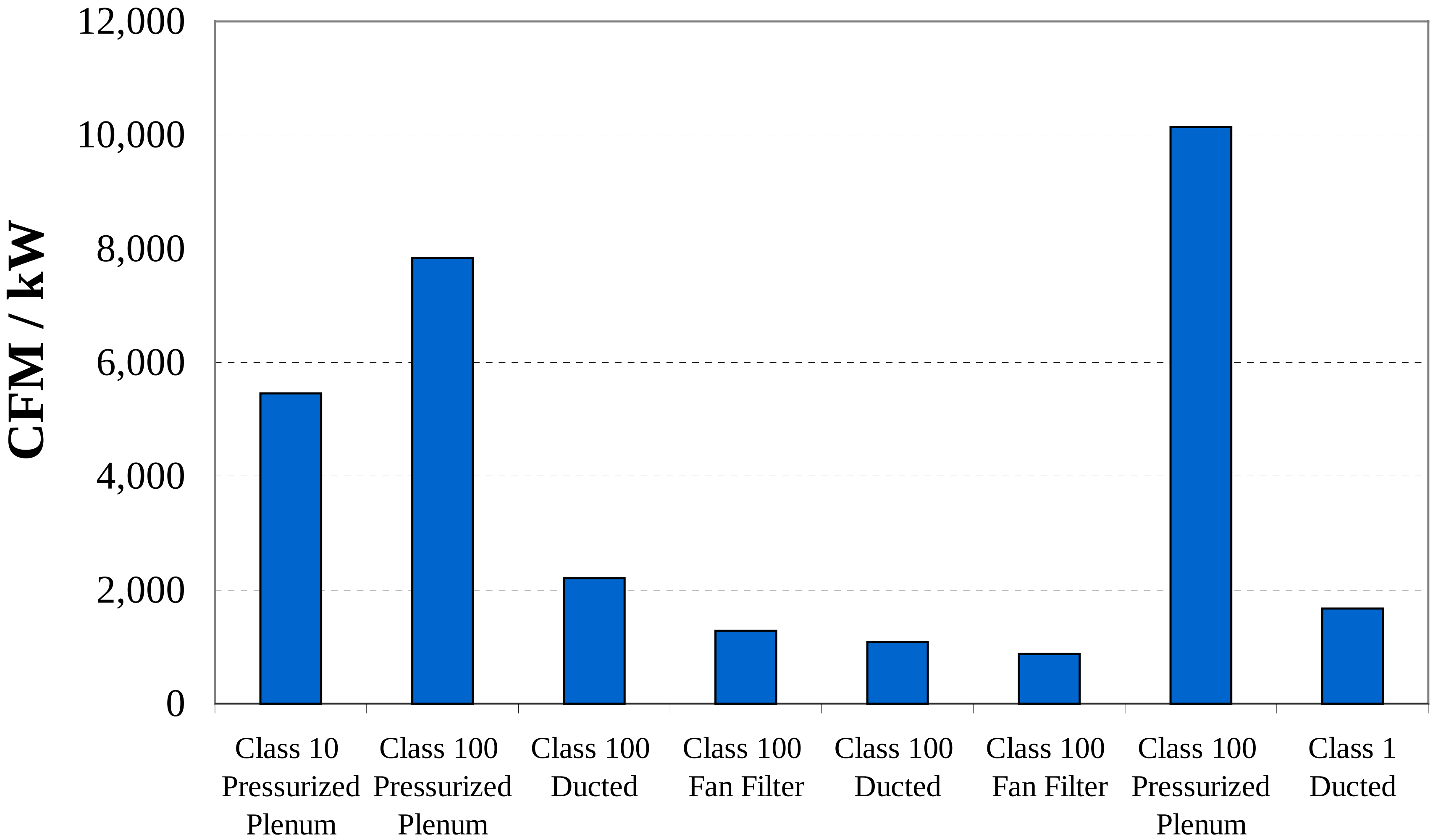
- Anonymous reporting
- Comparison of similar class systems
- Comparison of components
- Comparison of overall facility
- No production metrics

Energy Intensive systems

Recirculation of air in cleanrooms



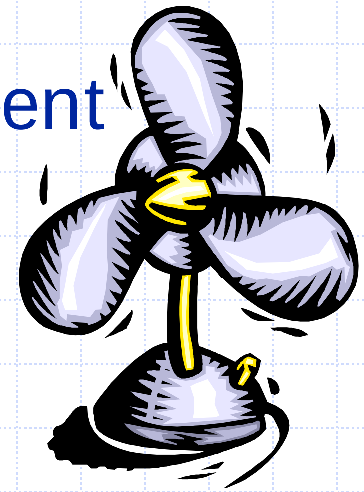
Recirculation Air Comparison



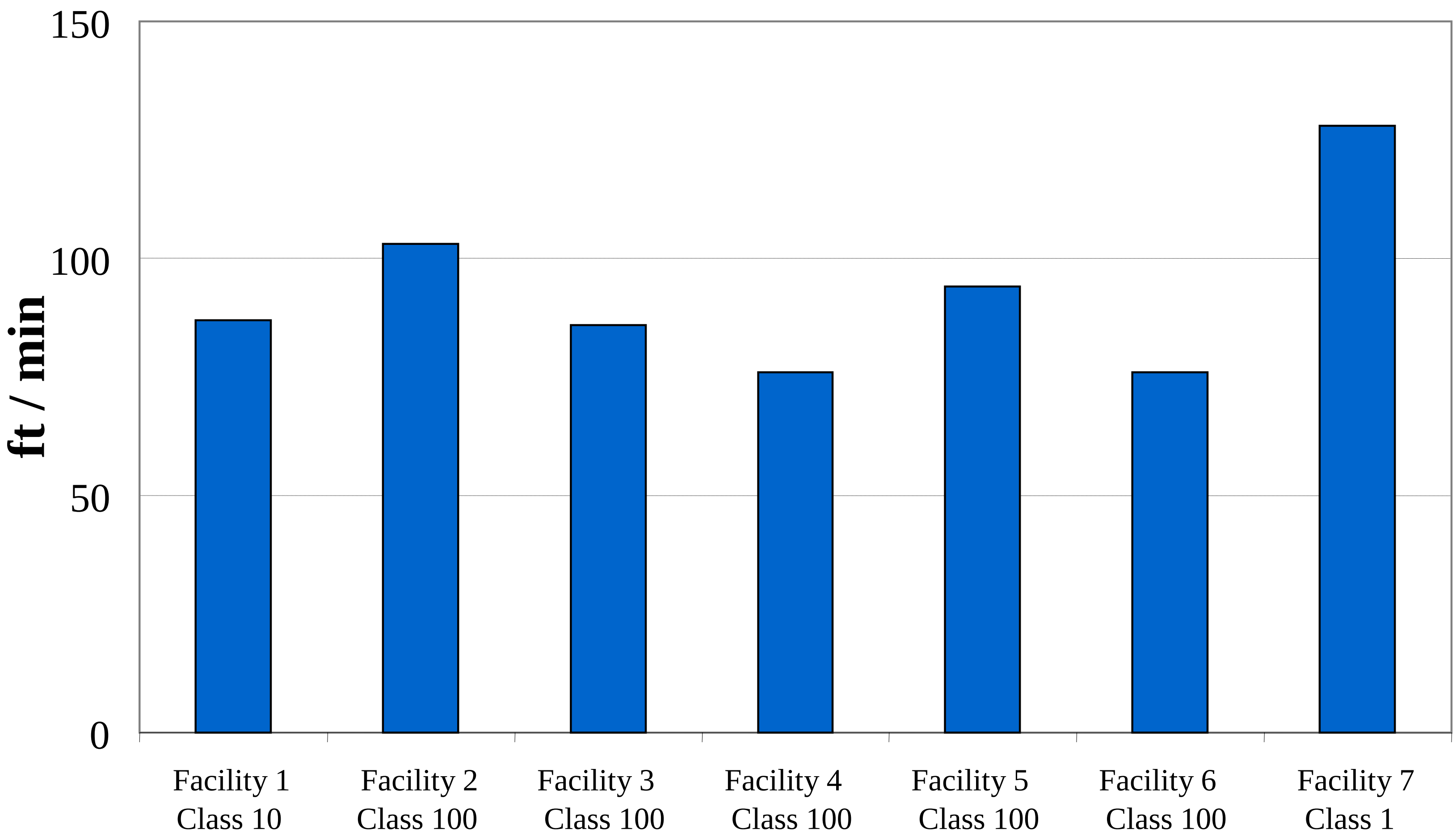
Recirculation System Observations

- Energy use for various air management systems varies by as much as a factor of 10
- Plenum systems (low pressure drop) are generally more efficient
- Ducted systems (high pressure drop) are less efficient
- Fan-filter units are relatively inefficient

  (but are improving)



Filter Velocity Observations

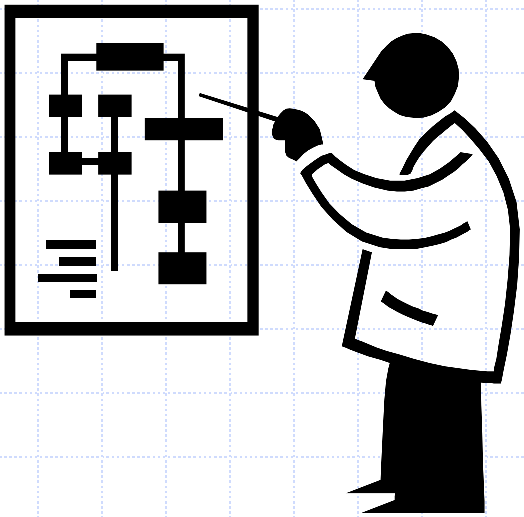


Variations in air flow velocities

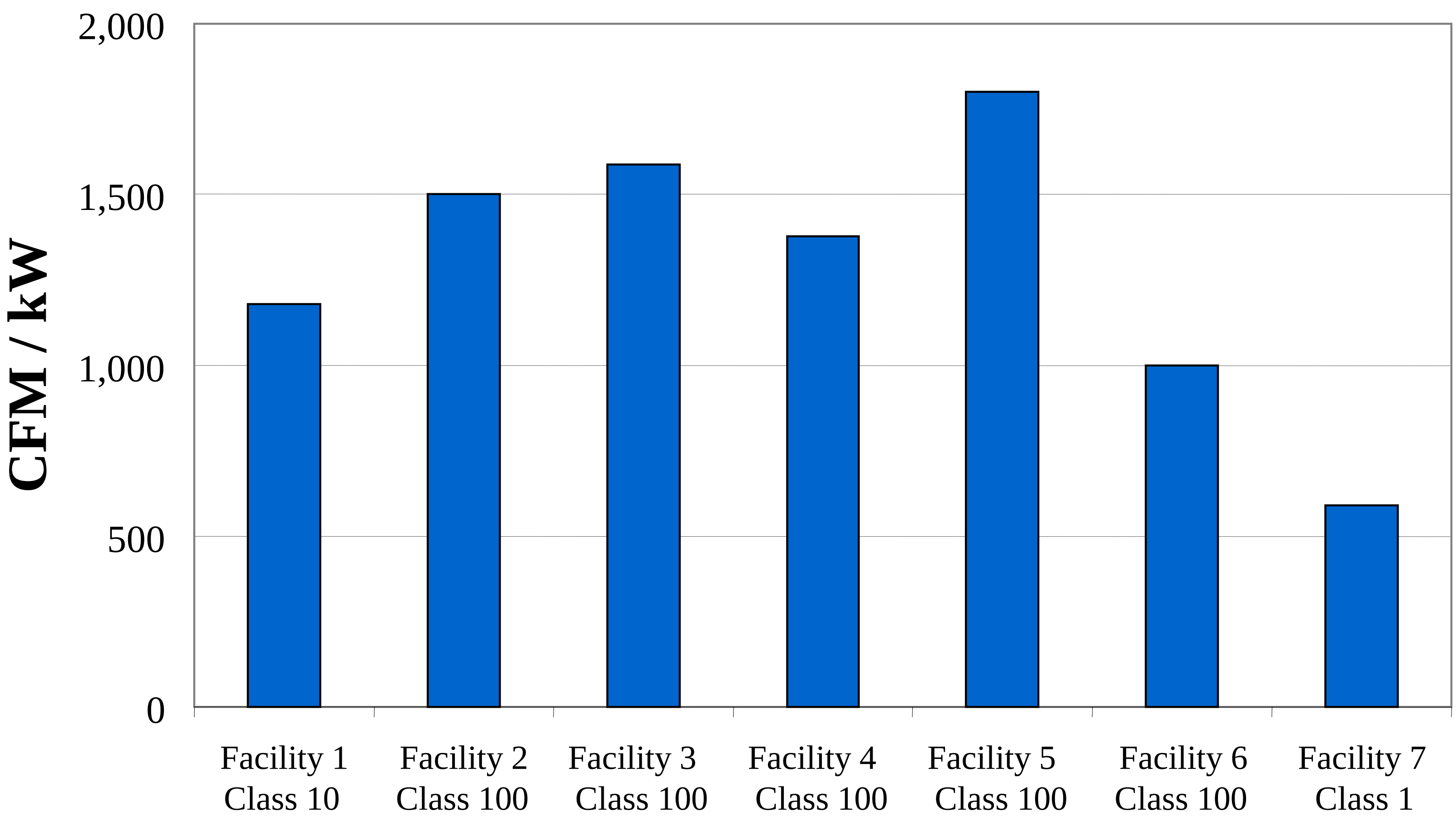
- The Institute of Environmental Sciences and Technologies (IEST) establishes recommended air change rates (velocities)
- Wide variation in air change rates observed
- Some measured values exceed IEST rates
- Performance of all rooms was acceptable
- Since energy varies as the cube of velocity, this is a huge opportunity

Filter Velocity Observations

- Understand the contamination control problem
- Select appropriate cleanliness class
- IEST recommended air change rates



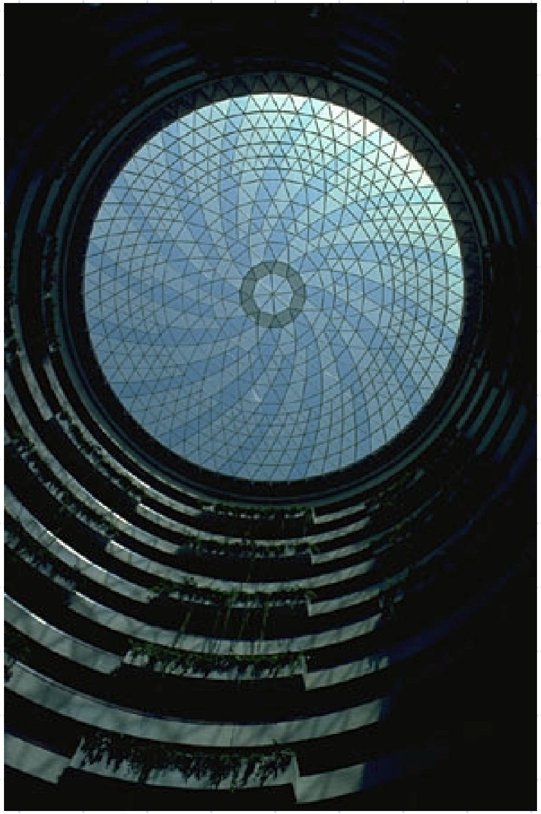
Make-up Air Observations



Make-up Air System Observations

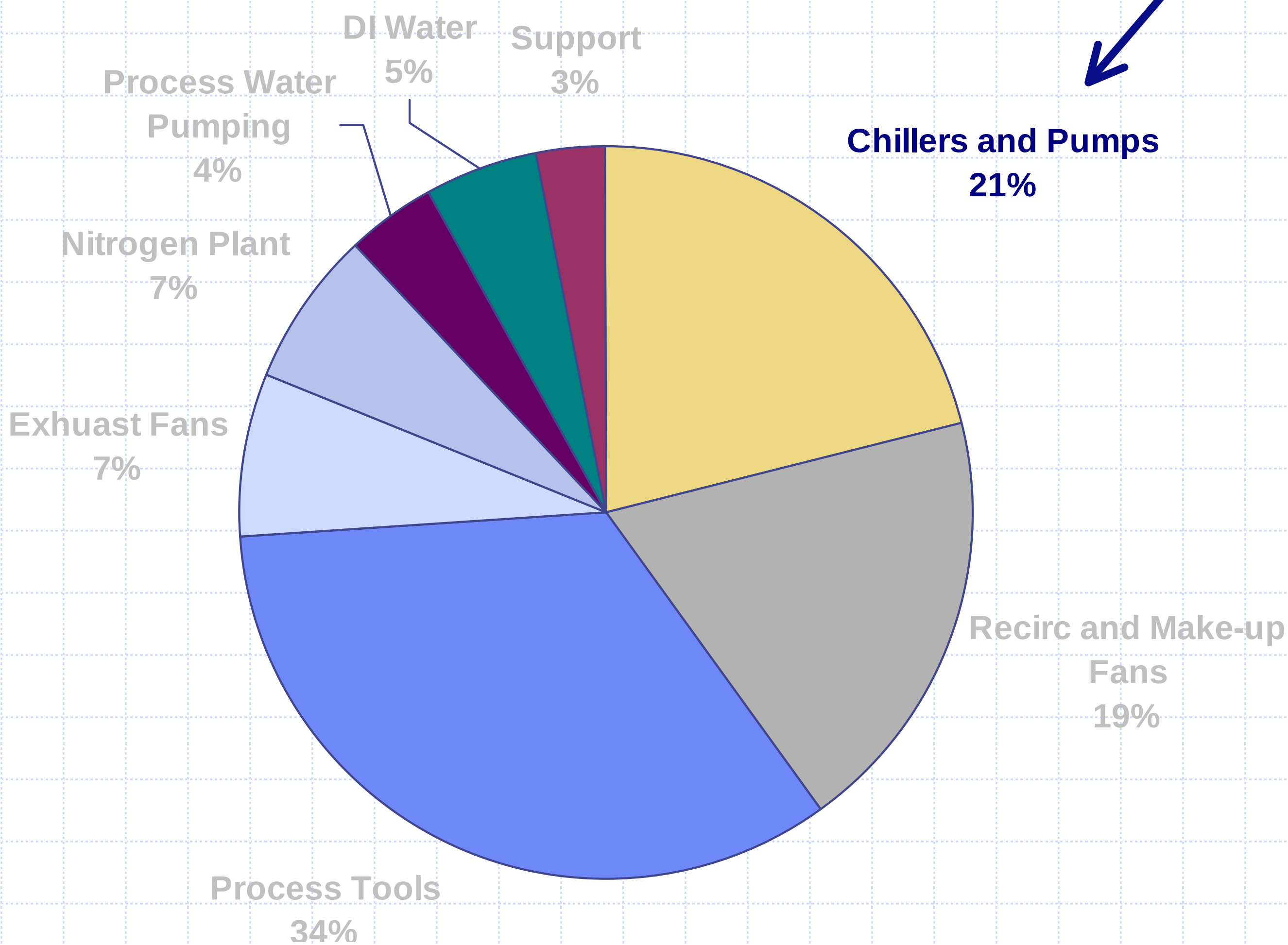
Efficiency is influenced by:

- Right sizing exhaust and pressurization
- Resistance of make-up air path
- Adjacency of air handler(s)
- Air handler face velocity
- Fan and motor efficiency
- VFD controls

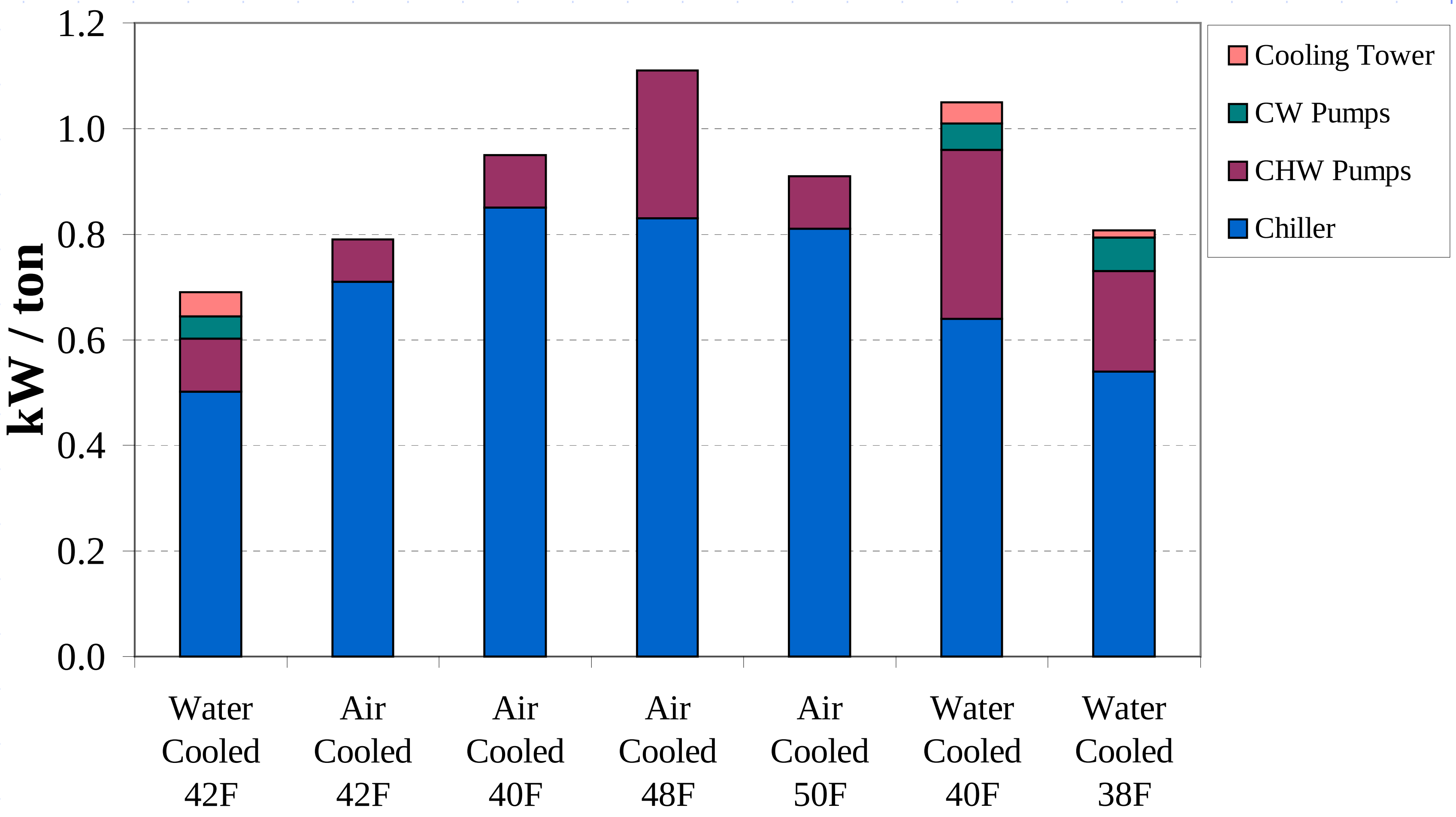


Energy Intensive Systems

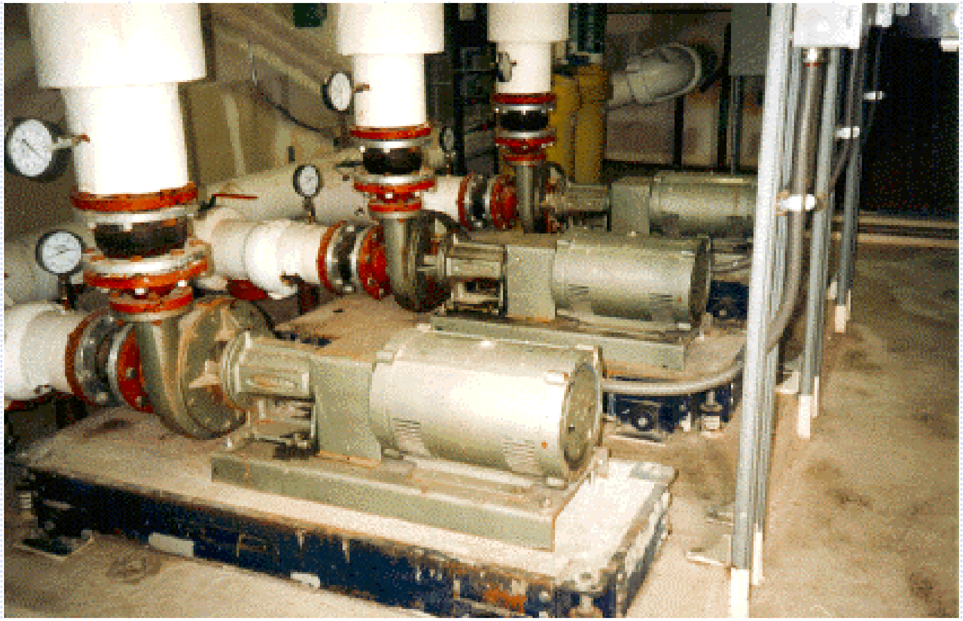
Chilled water systems



Chilled Water System Observations

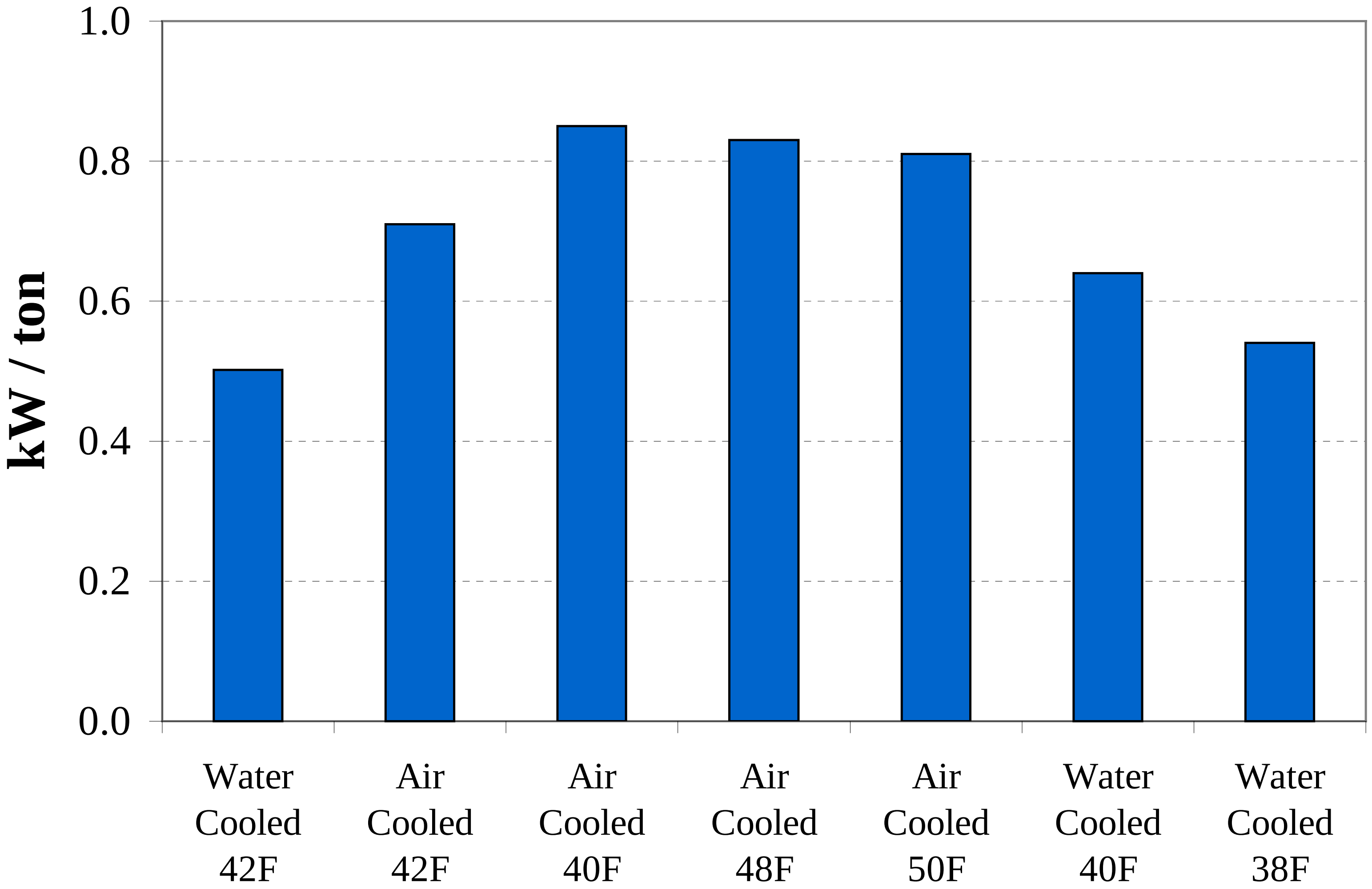


Chilled Water System Observations



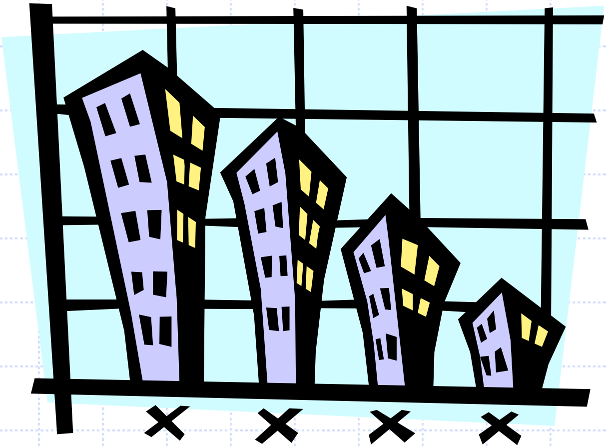
- Adjacency of central plant
- Chiller efficiency dominates, but
- Pumping energy can be significant

Chiller Comparison



Chiller Benchmarking Observations

- Wide variation in efficiency
- Air cooled chillers are less efficient
- Most efficient ~ .5 KW/ton range
- Chiller efficiencies well publicized, but
- Name plate is different than measured



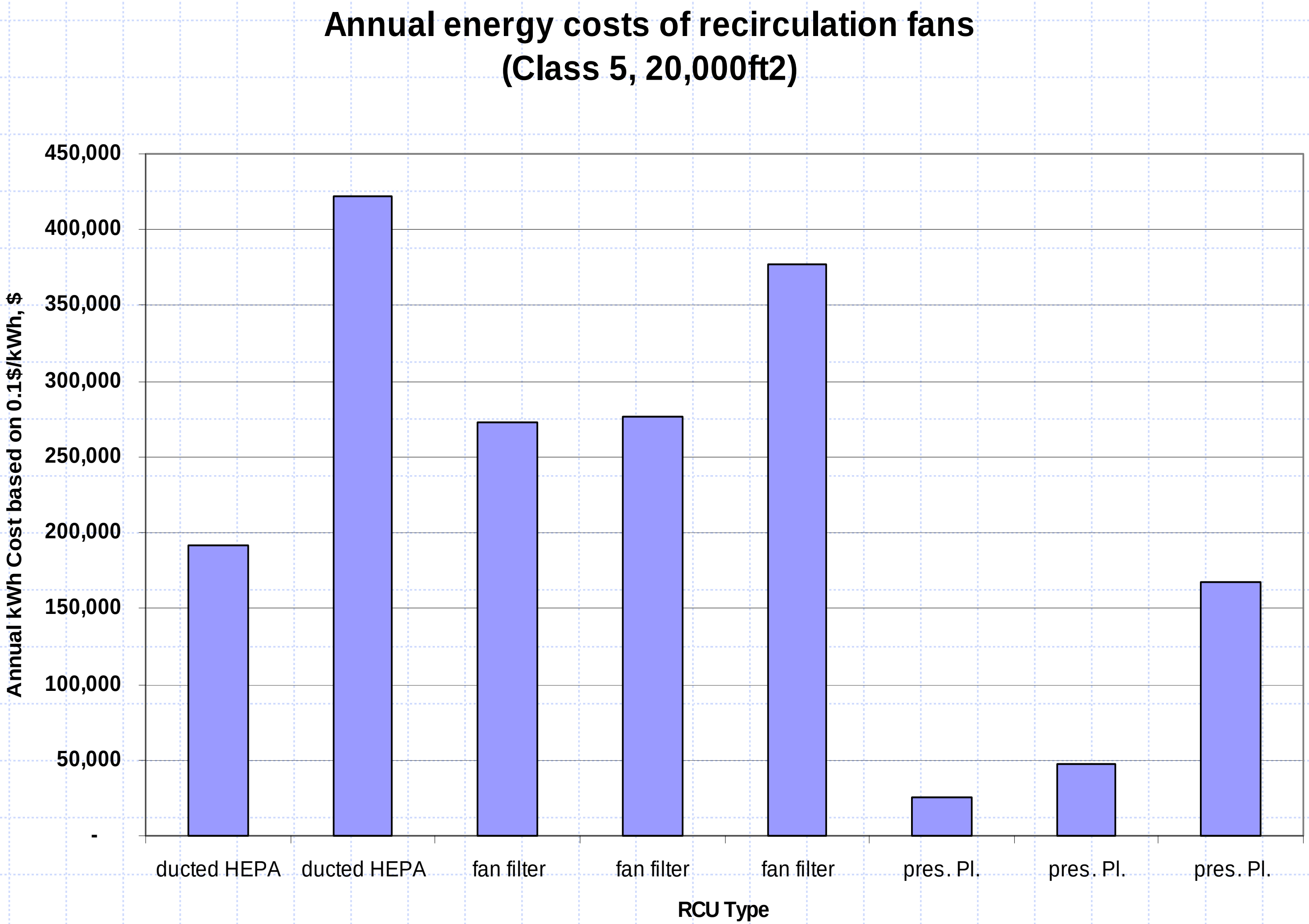
Process load Issues

- Electrical loads vary greatly depending upon the process in the room
- All of the electrical load is converted to heat which is removed by HVAC and process cooling systems
- Getting the design loads right is a challenge
- HVAC equipment sized correctly operates more efficiently
- Benchmark data can help determine design load for future projects

Best Practices

- Benchmarking can identify best practices:
  - Use of free cooling
  - Separate high temperature chiller
  - Use of multiple cooling towers
  - Reduce excess pumping
  - Recirculation air setback
- Benchmarking can identify maintenance problems

What is the cost impact?



Benchmarking Can Help Establish Efficiency Goals

- Energy Budget
  - **Total facility**
  - **End use**
- Efficiency Targets for key systems/components
  - **Cfm / KW**
  - **KW / ton**
  - **Pressure drop**

Benchmarking identifies Cleanroom Efficiency Concepts

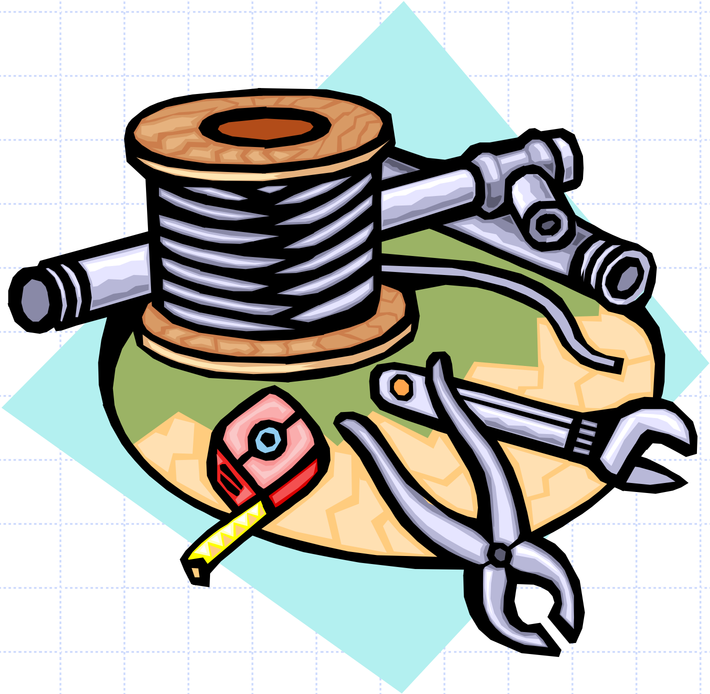
- Minimize Clean Space
- Cleaner than needed does not improve yield, wastes energy, and is expensive
- Move less air, pump less liquid
- Minimize flow resistance

Cleanroom Efficiency Concepts

- Chilled water temperature as high as possible
- Avoid simultaneous heating and cooling
- Minimize exhaust and leakage (and corresponding conditioned make-up air)
- Turn off when not in use

Efficiency Concepts (continued)

- “Large Pipes / Small Pumps” - lower pressure drops in air and water streams
- Lower face velocities in air handlers - 400 to 450 fpm versus 500 fpm saves 10% to 20% on fan energy



Cleanrooms Website

http://eetd.lbl.gov/cleanrooms/

Stay tuned for updates